

Moored Observations for the Forced Upper Ocean Dynamics Experiment in the Arabian Sea

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LONG-TERM GOALS

My long-term goals are to understand how biological processes in the ocean affect, and are affected by, physical processes (mixing, stirring, and the penetration of light into the ocean). I want to figure out how irradiance and wind-stress influence the dynamics of the upper ocean, how these dynamics govern the rate and nature of primary production, and ultimately, the growth of phytoplankton populations. I also want to understand the feedback between the changes in phytoplankton biomass and the variability in optical properties of the sea, and to use the absorption and scattering properties of phytoplankton to predict photosynthesis and growth.

OBJECTIVES

The scientific objectives of this grant are to (1) determine the diurnal, within-season, and seasonal variability of phytoplankton for a locale subject to strong seasonal wind-stress; (2) understand how POC:Chl changes with the advent of the SW monsoon; (3) determine whether the seasonal increase in phytoplankton affects the surface heating of the water column; and (4) determine whether the chlorophyll specific primary production is constant through the year in the Arabian Sea, where strong seasonal signals in nutrients are characteristic.

APPROACH

We participated in the mooring experiment in collaboration with Tom Dickey (UCSB), Bob Weller (WHOI), placing two Multi-variable Moored Sensors on the WHOI mooring which was deployed from October 1994 to October 1995. The general approach was therefore to collect high-resolution time series data to observe seasonal, as well as day-to-day and diel phenomena.

WORK COMPLETED

1. We made presentations of data at the Arabian Sea Workshop in August 1998.
2. We now have two papers in press for the Deep-Sea Research-II Special Volume on the Arabian Sea Expedition (Marra et al., in press; Kinkade et al., in press) and were co-authors on three other manuscripts, also 'in press.'

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3. We submitted one manuscript for the second volume of the Arabian Sea program (Kinkade et al., submitted)
4. Presentations were made at the Ocean Sciences Meeting, held in February 1998.

RESULTS

The yearlong mooring records show clearly the semi-annual biological response to the northeast and southwest monsoons. Interestingly, prior to each mixed-layer deepening associated with the monsoons, there is evidence of mesoscale eddies passing the mooring site, and which contain enhanced quantities of chlorophyll. Each monsoon causes the mixed layer to deepen, but for the northeast monsoon, convective processes dominate, while during the southwest monsoon, the mixed layer deepens via wind-induced mixing. During both mixing periods, chlorophyll declines, and then increases as the water column stratifies. The annual cycle of chlorophyll variability at the mooring site (the climatological center of the Findlater Jet, 15°30'N/61°30'E) generally follows the mixed layer depth. When the mixed layer is deep, the quantity of chlorophyll in the water column is low, and increases when the mixed layer shallows following the cessation of monsoon winds. Prolonged stratification, during the intermonsoons, also results in declines in photosynthesis.

The variability in productivity over the year generally follows the change in chlorophyll (see Fig. 1 from Marra et al., submitted), except where there may have been changes to community structure (Feb-Mar, '95), or when grazing might be important (May, July, '95).

Strong diel variability in phytoplankton and particle variables were observed, and coherence analysis indicated that these were modulated more by water column processes (e.g., changes in the mixed layer depth) than by solar variability (Kinkade et al., submitted).

IMPACT

We have demonstrated the utility of moored sensor systems in an unforgiving environment. The high-resolution data are extremely useful to those trying to understand the drivers for seasonal variability in productivity. The seasonal variability in productivity is crucial to interpret the export of carbon from the surface ocean to depth and also to the development of algorithms for calculating productivity from satellite imagery. The results will fuel consideration of the importance of diel processes in determining the activities of plankton. We now have a better idea of the relationships among phytoplankton production, nutrient supply, and changes in mixed layer depth. The importance of mesoscale processes in distributing heat and momentum was demonstrated over a large part of the study area, and is probably the reason why productivity can remain relatively high despite the extreme variability in wind-forcing.

TRANSITIONS

During this project we have developed a low-cost, compact, easy-to-use moorable spectro-radiometer with 32 wavelengths. It should find a variety of uses. The most recent issue of *Sea Technology* (Sept., '97) has advertisements by four companies selling in situ fluorometers. I think that the efforts by both

the LDEO and UCSB (T. Dickey et al.) have had something to do with the use of chlorophyll fluorescence measurements at sea.

RELATED PROJECTS

We are collaborating with others in the overall Arabian Sea Program (including JGOFS), contributing to studies of shipboard productivity measurements (R.T. Barber and myself), the moored sediment trap program (e.g., C. Lee and S. Honjo), air-sea interaction (R. Weller, A. Fischer). I am continuing the comparison of results here with previous mooring programs, primarily to examine further diel variability in the moored-sensor variables with other kinds of rate measurements.

PUBLICATIONS

Kinkade, C.S., J. Marra, T. Dickey, C. Langdon, D. Sigurdson, R. Weller. 1997. Diel variability of bio-optical signals in the Arabian Sea. Deep-Sea Research-II (in press).

Marra, J., T.D. Dickey, C. Ho, C.S. Kinkade, D.E. Sigurdson, R. Weller, R. T. Barber. 1997. Variability in primary production estimated from moored observations in the central Arabian Sea in 1995. Deep-Sea Research-II (in press).

Rudnick, D., R.A. Weller, C. Eriksen, T.D. Dickey, J. Marra and C. Langdon. 1997. One-year moored observations of the Arabian Sea Monsoons. EOS 78, pp. 117, 120-121.